AD-A102 698 CENTER FOR NAVAL ANALYSES ALEXANDRIA VA INST OF NAVAL--ETC F/G 5/1
DEPENDENCE, RISK, AND VULNERABILITY.(U)
JUN 81 J THOMASON
UNCLASSIFIED CNA-PP-307 NL

1 OF 1
AD
A102698

END
DATE
FILMED
9-81
DTIC

9 (14) CNH-PP-

PROFESSIONAL PAPER 307 / June 1981

LEVEL II

2

AD A102698

DTIC FILE COPY

(6)

DEPENDENCE, RISK, AND VULNERABILITY.

(10)

James Thomason

(11) Jun 81

(12) 49

403542

CNA

CENTER FOR NAVAL ANALYSES

81 8 11 001

PROFESSIONAL PAPER 307 / June 1981

DEPENDENCE, RISK, AND VULNERABILITY

James Thomason

Institute of Naval Studies

CENTER FOR NAVAL ANALYSES

2000 North Beauregard Street, Alexandria, Virginia 22311

I. INTRODUCTION

The purpose of this paper is to articulate a framework for interrelating the concepts of dependence, risk, and vulnerability. To do this we first distinguish dependence (susceptibility to utility losses) from risk (the probability such losses will be inflicted). Then we relate these two concepts through the idea that vulnerability is the expected value of such potential utility losses. Among other things, this approach enables us to highlight those strategies that attempt to reduce vulnerability by lessening dependence and those which aim to reduce vulnerability by lowering the probability that such utility losses will be imposed.

In the second section of this paper, we define dependence and distinguish between two fundamental subtypes -- "positive" and "negative." The third section presents a viable general technique for measuring dependence. Section four considers the relations among dependence, risk, and vulnerability. Section five is concerned with strategies for reducing vulnerability. Concluding remarks follow in section 6.

II. TWO TYPES OF DEPENDENCE: POSITIVE AND NEGATIVE

An actor (A) is dependent on another actor (B) at time t if B can cause a reduction in A's utility at t if B chooses to do so; this is both a necessary and sufficient condition for A to be dependent on B. However, there are two very different subtypes of dependence. For convenience we label them "positive" and "negative."

The distinction between positive and negative dependence hinges on the relation between changes in the extent of the actor's dependence and changes in the dependent actor's utility level. Increases in A's positive dependence on B will (definitionally) result in greater total utility for A, at least other things equal. By contrast, any increases in A's negative dependence on B will not result in such increases in A's utility level, other things equal; such increases will probably (but not necessarily) lead to decreases in A's current level of utility. Inattention to this distinction may be at the core of much ambiguity in the current "dependence" literature. Let us try to elaborate.

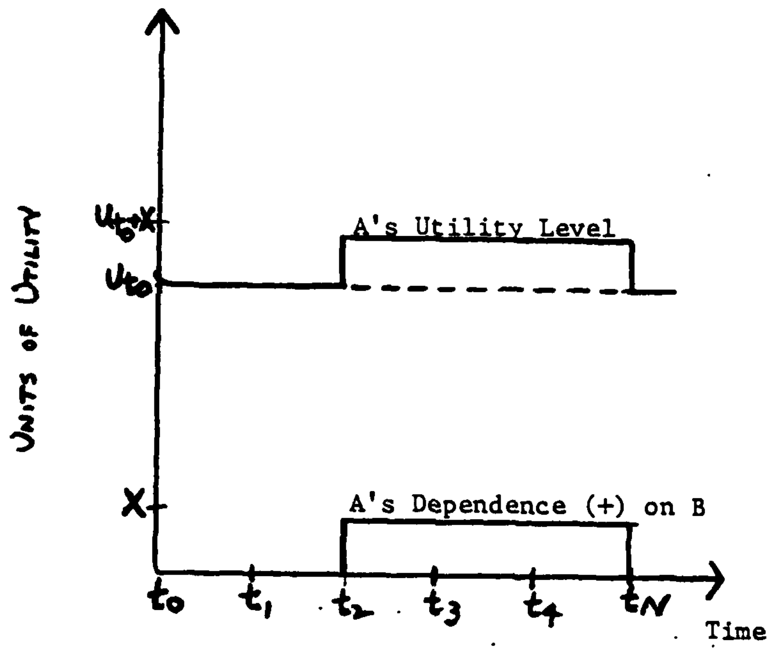
Consider a simple, stylized case in which A is not dependent on any other actor at t_0, e.g., A is completely isolated from all other actors at that initial time. In fact, for simplicity assume that no other actors exist or at least that none can con-

tact A in any way. Also assume that at t_0 A has a total utility or level of well-being equal to U_{t_0} per year.

Into this rather stark world arrives a second actor, B, at time t_1. Then at t_2 B begins providing A with a stream of goods -- free of charge -- which A is delighted to have and which increases A's level of utility by X per year. Beginning at t_2, therefore, A now starts to enjoy a utility (per year) higher than at t_0 or t_1, i.e., $U_{t_2} = U_{t_0} + X$.

B is thus by t_2 providing A with goods A wants at less cost than A could otherwise have obtained them. By adding to A's utility in this ongoing way, B has made A more dependent on B at t_2 than A had been at t_0 or t_1 -- that is, more <u>positively</u> dependent. Other things equal, moreover, B can at t_3 impose more harm on A than it could at t_0 or t_1, because B can take away something in the next period that it is now giving to A. At t_0 or t_1 it was not giving anything it could take away. By providing a stream of benefits to A, B is now in more of a position to harm A's (new, higher, t_2) level of utility than it was before it began providing the benefits to A or would be if it withdrew them. Finally, if B did withdraw those benefits (at t_n) A would be less dependent at t_n than at t_2 -- but also back at a lower total utility level (U_{t_0})[1]

Figure 1: Effects of Changes in A's Positive Dependence on A's Utility Level



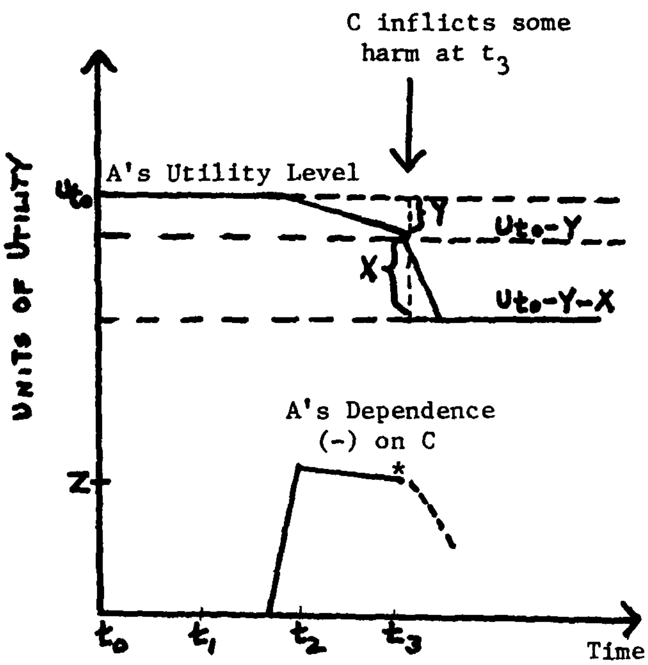
Now, on the other hand, consider a case of increasing negative dependence. This can be viewed as any increase in the ability of one actor (B) to impose harm on the (increasingly) dependent actor (A), but <u>without any commensurate utility gains for the dependent actor</u>. Examples would be increases in B's ability to do greater physical damage to A, or in B's ability to increase the prevailing market price for a good demanded by the other actor (but in the absence of a prior, downward effect on the market price),[2] etc. To illustrate, we focus on the ability to do physical damage.

As before, imagine (as in figure 2) that at t_0 A is totally out of even potential contact with all other actors. Assume, too, that at t_0 A again has a total utility equal to U_{t_0} per year. Now at t_1 actor C arrives, and is completely unarmed. By t_2, however, C, while engaged in no ongoing contacts with A, has developed weapons it could use to inflict some damage on A if C so

FIGURE 2 HERE

chooses, which could thereby decrease A's level of welfare. Although A may have developed the capacity (between t_1 and t_2) to physically prevent some of C's new missiles from reaching its territory should C launch them, let us say there is a certain amount of damage (Z), that C can do to A regardless. At t_2, A is more negatively dependent on C than it had been at t_0 or

Figure 2: Effects of Changes in A's Negative Dependence on A's Utility Level



Y= total amount of resources A spends per period just prior to t_3 to reduce expected damage
X= harm imposed by C at t_3

* (see footnote 3)

t_1. But note that in this case A's utility level at t_2 has not increased (relative to what it had been at t_0 or t_1) despite this increase in dependence of A on C by t_2. In fact, A's current (t_2) utility level may well be (but need not be) less than at t_0 or t_1. It probably will be less because A is likely to be diverting resources (shown in figure 2 as costing Y in A's utility by t_3) from production of consumption goods to its self-defense (when it would rather not have to protect itself). But, on the other hand, A may "enjoy a fight" (not illustrated), or simply be unaware of such increases in C's ability to inflict such damage (and so its utility until t_3 might remain at U_{t_0}). In this kind of general case of increased negative dependence of A on C, if C in fact inflicts X units of harm on A at t_3, then, as in the case of positive dependence, A's level of utility will clearly decline (by X units) compared to U_{t_0}, other things equal. But recall that in the case of negative dependence, A's t_2 utility was no higher than it had been at t_0 or t_1. Consequently, A's utility level at t_3 will (generally) have declined below what it had been prior to the dependence.[3] In the case of positive dependence, however, any reductions in positive dependence will only (in general)[4] return the dependent party to its pre-dependence level of utility, at least other things equal.

III. MEASUREMENT STRATEGIES: DEPENDENCE

This fundamental conception of A's dependence on B -- as equivalent to a situation in which A can be hurt (suffer utility loss) by B -- begs for elaboration in degree. In other words, how are we to distinguish variations in actors' dependence on other actors?

Dependence vs. Vulnerability

As noted in the introduction, we view dependence and vulnerability as distinct concepts. Vulnerability is not herein construed as a type of dependence. This contrasts with Keohane and Nye's (1973) formulation of the concept, for example, so it is well to be specific about our differences. Keohane and Nye distinguish between sensitivity and vulnerability "dependence." We strongly agree with Baldwin (1980) that "sensitivity dependence" implies nothing more than the minimal connectedness of behaviors or parts in two or more (nominally) distinct social systems. We believe (with Baldwin), that Keohane and Nye's "vulnerability dependence" (defined as "continued liability to costly effects imposed from outside, even after efforts have been made to alter or escape the situation")[5] is analytically closest to the meaning of dependence (as we define it) -- a hurt can be imposed if the actor you depend on so chooses. But dependence need not imply more than a minimal probability that the hurt will be imposed. As

we view it, how vulnerable to a given amount of hurt a dependent actor is -- with the amount of hurt (i.e., utility loss) he could receive being the measure of his dependence -- will vary with the chance that the given amount of hurt will be inflicted.[6]

In the recent literature on <u>trade</u> dependence (e.g., Caporaso, 1978; Baldwin, 1980) the notion of measuring A's import dependence on B as the "opportunity cost" involved in A's being forced to shift from B to its next best possibility has gained increasing favor. While we also believe that a dependence formulation in terms of opportunity cost is appropriate, we have yet to see either an articulation of just what would be involved in such a measurement strategy or a comparison of an opportunity cost approach with a so-called "consumer/producer surplus" approach to the losses an importer (A) would sustain if a particular seller did the maximum damage it could to A, to the market, or to both. Such a discussion may help shed some light on the key issues involved. For one thing, A may be dependent on sellers with which it has no direct market exchanges, which suggests that the bilateral formulation of opportunity cost just mentioned is too restrictive. For another, the opportunity cost of being forced to shift to one's next best alternative is a meaningless phrase in terms of the strict definition of opportunity cost in the economic literature. Thirdly, and more importantly, the consumer/producer surplus framework, while eminently sensible (though not perfect) for assessing the utility losses to A due to a given world price

increase for a commodity A is buying, is insufficient to identify the amount by which a particular seller can affect the market price. The remainder of this section will elaborate on these points and, in so doing, describe the applicability of the consumer/ producer surplus approach as part of an overarching (generalized) opportunity cost framework for gauging one actor's import dependence on another party or group of actors. After doing so, we will then proceed to an examination of the major considerations which seem to be involved in assessing one actor's vulnerability to hurt by another. In the last section of the paper we will then briefly examine some of the strategies and policies a dependent actor may want to adopt to reduce its vulnerability.

Dependence as Opportunity Costs

The idea of an opportunity cost can be simply stated. When A does X_1 with a given amount of resources, he does not do X_2, X_3, etc., with those resources -- so long as these are mutually exclusive options. If X_2 is his next best alternative to X_1, the opportunity cost to A of doing X_1 is the total value to A were he to do X_2 instead.[7]

Note that the opportunity cost concept is not defined as either the net loss to A of being forced to do X_2 instead of X_1, nor as the net benefit to A of doing X_1 rather than X_2.

Rather, it is the total value of one's next best alternative if one is doing X_1. However, dependence as we define it is really the amount of loss one would incur in being forced to move to one's next best alternative (X_2), rather than being allowed to continue doing X_1.

In any case, if this concept is applied to A's dependence on a particular foreign supplier (B), consider first the simple situation in which B is one of an infinite number of suppliers of the commodity (i) A is interested in. Assume further that A is importing most of the commodity i it imports from B, but that this amount represents an infinitessimal amount of the total amount of i for sale on the international market. Now if B suddenly stopped producing i, or if B continued to export i but refused to sell i to A, A's opportunity cost would equal the benefit from the initial situation; A would incur no net loss because B was completely powerless to influence the market price for good i. There might be minor transactions costs for A due to the move to some new supplier, but these would be so small as to be irrelevant.

At the opposite extreme, if B were one of very few suppliers of i in the world, if A imported i, and if B suddenly significantly raised its asking price for i, what would A's net loss be if forced to shift to its next best alternative? The costs to A in this case will hinge critically on several factors, including the price elasticity of supply of i, A's price elasticity of demand

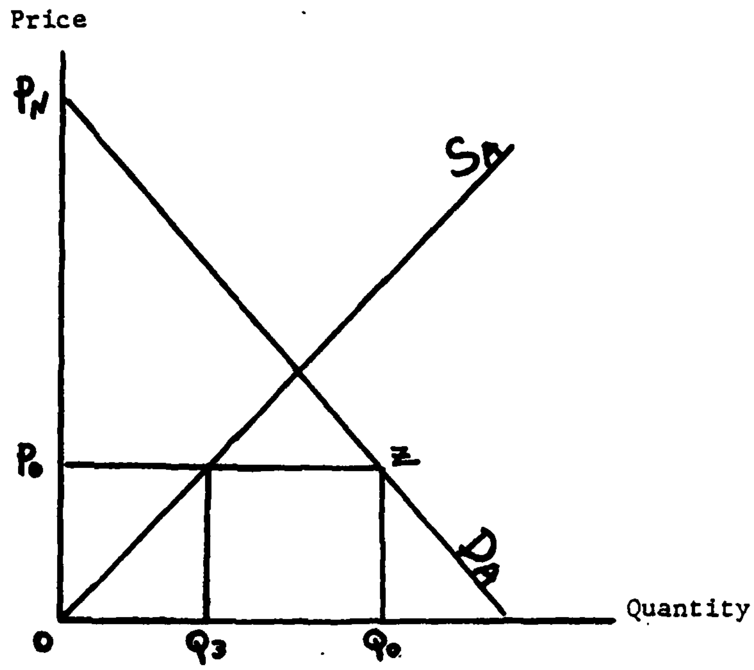
for i, and the quantity of i A had previously been importing. All these factors -- plus the reduction in the amount of i B will supply to the market -- will jointly define the amount of the loss A would sustain as a consequence of B's action (note that this specific action by B may not be the most damaging action of which it is capable; it might have stopped exporting i altogether). We define A's actual dependence on B as the maximum amount of damage B can impose on A if it so chooses. The specific way in which these factors combine, and the amount of loss A will sustain in this case, are depicted graphically in figure 3b.

First, though, it may be useful to clarify some fundamental referents in this approach. Figure 3a illustrates the situation confronting A prior to such a price increase.

FIGURE 3a HERE

In figure 3a, party A is consuming quantity Q_o of commodity i and is paying price P_o per unit of the i it consumes. S_a represents A's domestic supply curve for i and D_a represents A's domestic demand curve for i. P_o is the prevailing global market price for i. Domestic producers are supplying quantity Q_3 of good i to A, and foreign suppliers are supplying the remainder, i.e., Q_0-Q_3. As can easily be seen, domestic producers are receiving revenues equal to $P_0 \cdot Q_3$ from A's users of i, while foreign suppliers are receiving revenues equal to $P_0(Q_0-Q_3)$

Figure 3a: Baseline situation A confronts prior to price increase



from A's users of i. A's users of i are thus paying $P_o \cdot Q_o$ to obtain Q_o units of good i (per period, e.g., per year) in this situation.

But now note that in any situation such as this, A's users of i are receiving greater utility from these purchases than they are being required to pay for. This extra utility can be labelled a "consumer surplus." (In fact, it can be thought of as "gains from trade".)[8] In this situation, A's users are receiving a consumer surplus equal to the large triangular area in figure 3a (bounded by the vertical line P_o, the distance on the vertical axis P_n-P_o, and the hypotenuse running from P_n to Z on A's domestic demand curve).

The key to this idea of a consumer surplus is that, at any price short of P_n, at least some of A's consumers of i are able to buy commodity i for less than they would be willing to pay for it if they had to. In fact, the prices they would be willing to pay for various marginal amounts of i are represented by the domestic demand curve (Da).

Now, given this, if B was able to suddenly increase the prevailing market price from P_o to P_1, a basic measure of A's <u>total</u> loss of utility due to such an increase would be the sum of the areas 1, 2, and 3 in figure 3b. Although several refinements can be offered, they are all elaborations on this basic measure-

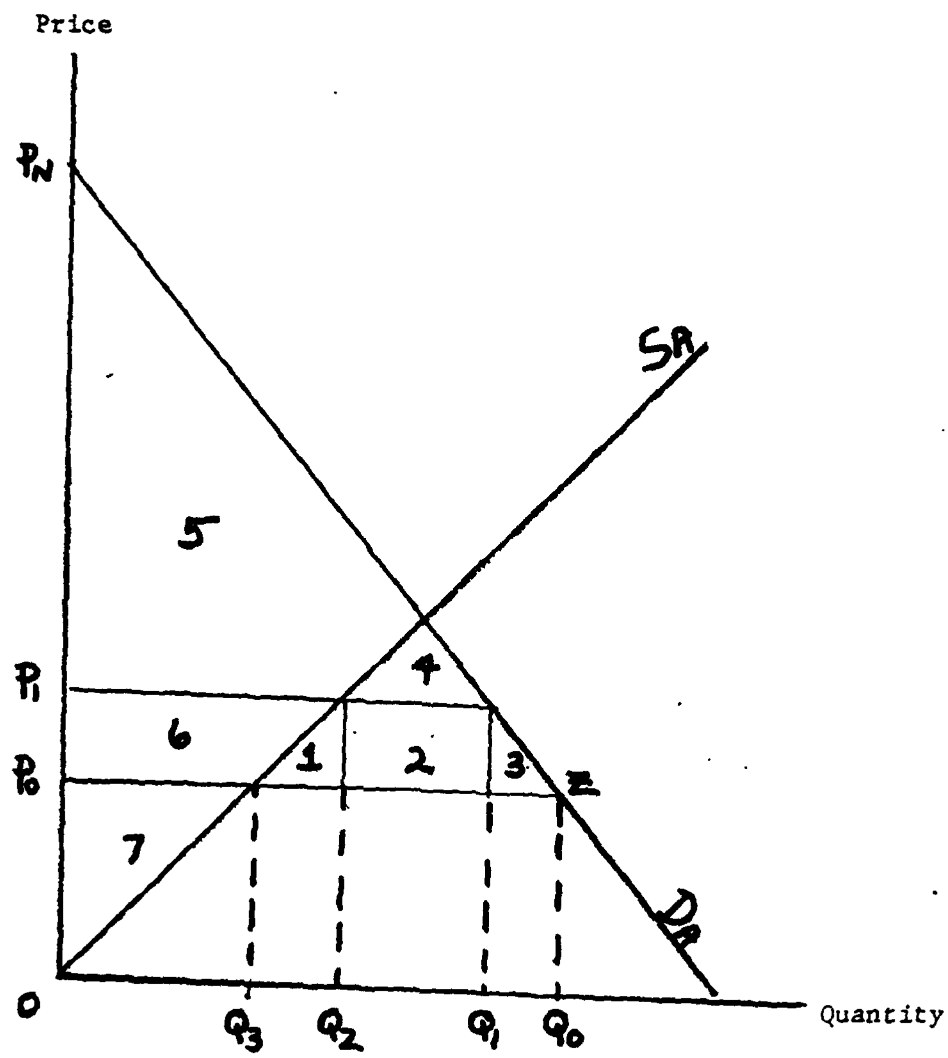
ment procedure. A description of the logic and assumptions underlying this measure strategy may be in order.

FIGURE 3b HERE

With an increase in the prevailing market price for i (from P_o to P_1), A's users will pay more per unit and consume less, A's domestic producers of i will be able to sell more i (to A's users) at higher prices, and A's domestic producers will waste resources on the production of this extra i (compared to the greater efficiency enabled when the global market price was P_o). In sum, A's users of i will lose consumer surplus. Some will be lost to foreign producers (area 2), some will be lost to domestic producers (area 6), some will be a so-called "deadweight loss" (area 3) -- gained by no one -- and some will be lost to inefficient use to produce i within A (area 1).

Now considered as a single entity, A's total utility loss (as opposed to simply A's users' losses of consumer surplus) from this price increase will be equal to its consumer surplus losses (areas 1, 2, 3, and 6) offset by the "producer surplus" gained by domestic producers (area 6) in the process -- i.e., the revenues domestic producers themselves now receive from A's users over and above their costs of production of i. (Area 6 can be seen to be over and above the costs of production because it is <u>outside</u> the area

Figure 3b: Fundamental components of consumer/producer surplus analysis



bounded by the domestic producers' supply curve (S_a), which is in effect a line depicting domestic producers' marginal cost of production of i.)

Note that even at price P_1, however, A's users of i still continue to receive a consumer surplus in their purchases of i. At P_1 this remaining consumer surplus will equal areas 4 plus 5 in figure 3b.

Now to actually estimate the dollar value of the utility loss to A per period that would be involved in any such shift in price as depicted in figure 3b, we can use the following basic equation -- which represents the area under the domestic supply and demand curves <u>over the price range</u> P_0 to P_1:

$$\text{Utility loss to A per period} = \int_{P_0}^{P_1} [S_a - D_a]dP$$

<u>Refinements and Limitations</u>

This framework offers the most basic measurement strategy for assessing A's (per period) utility losses due to a price increase of the sort just described. As mentioned, a number of refinements are possible. Two such possiblities are now presented.

First, domestic supply and demand elasticities are typically larger the longer the period considered. For this reason alone, in calculating the total utility losses due to a given price increase, costs per period will be highest in the short-term, less in the mid-term, and least in the long- run. Secondly, consider that individuals are known to attach higher value to losses (and benefits) in the short-term than in the long-term, even if the anticipated inflation rate is zero. Therefore, in calculating the total utility losses A expects to sustain over a given period of time, a procedure known as discounting[9] has been developed -- to reflect A's presumed relative concern about immediate losses versus losses in the longer run.

In any case, this kind of basic framework seems essential in any efforts to gain a systematic handle on the "hurt" that a specific type of event will impose on a particular consuming nation A. This does not mean it can be easily applied, with no honest differences of opinion in the assessment of damage that a given society would sustain if confronted by a partial supply disruption. As we see it, a number of uncertainties and difficulties are relevant here.[10] First, relevant parameters, particularly price elasticities of supply and demand, are open to significant and legitimate debate for most goods. This problem is the more difficult since the sorts of price increases implied by some kinds of supply disruption scenarios of interest to us are outside the range of prior experience.

Second, there are questions about the distribution of the losses sustained within A. Third, this utility loss measurement procedure (as outlined) does not capture all the further losses in secondary markets which use good i as inputs to production. Fourth, this framework does not fully capture A's losses due to reduced demand for A's goods abroad due to a "depressed" international economy. Fifth, some arguable assumptions about the constant marginal utility of the dollar are made.

Sixth, potential political and security costs of possible price increases have never to our knowledge been incorporated within this measurement framework. Perhaps they can be, although this is not well understood at present. Potential political costs to A may include loss of support from other actors and loss of influence. Potential military/ security costs might include increased difficulty of attaining specific security objectives.[11]

Seventh, A is assumed not to derive positive utility from any such price increase nor from the prospect of an international challenge. Yet there may be members of A who are thoroughly delighted at the chance to "wreak revenge." Moreover, a significant disruption may be viewed by some members of A as a "necessary" lesson to A in the importance of self reliance, in the reality of external threats, in the importance of a better strategy, etc. These are legitimate problems. But this framework can still

serve as the basic measurement strategy -- with refinements added as they are more clearly understood. Some problems will be intractable, but all we can do is make suitable assumptions and avoid decisions which blindly ignore their intractability.

While a consumer/producer surplus framework can in principle allow us to gauge the utility losses A would sustain due to a given price increase for a unit of good i, to assess the harm a particular actor B could impose on A demands additional information.

For example, in the case of A's import dependence on B, we need to at least determine how much of an adverse effect the particular supplier (B) can have upon the prevailing world price for the commodity in question. (We assume here for simplicity that B is not selectively subsidizing A's purchases of i below the prevailing global price.) Recall that, in figure 3b, it was the shift in the world price for commodity "i" (from P_0 to P_1), which occasioned A's utility losses equal to the sum of areas 1, 2, and 3. Consequently, to assess A's import dependence on B we need to determine how large a price increase B can impose on A insofar as A's imports of i are concerned.

To assess this it is convenient to refer to a simplified version of the international market for commodity i. This is shown in figure 4. The global demand curve for "i" is given as

D_G. The global supply curve is given as S_{G_o} at time t_o. At t_o, quantity Q_o is being supplied (and purchased) at a prevailing global price P_o.

FIGURES 4 AND 5 HERE

Assume that at time t_1 supplier B withdraws all its exports of i from the market. This quantity is represented by Q_o-Q_1, where Q_1 represents the total supply of "i" left for purchase on the market at t_1 after B withdraws. This action will lead to a shift in the supply curve (from S_{G_o} to S_{G_1}) and an increase in the the prevailing world price from P_o to P_1. Our object here is to determine the value of P_1.

Now assuming we know the slope of D_G and the potential change in quantity supplied (Q_o-Q_1), we can estimate the change in the prevailing global market price P_1-P_o (and the expected new market price P_1), as follows.

If the slope of D_G can be represented as:

Figure 4: Initial effect on world price of drop in B's supply

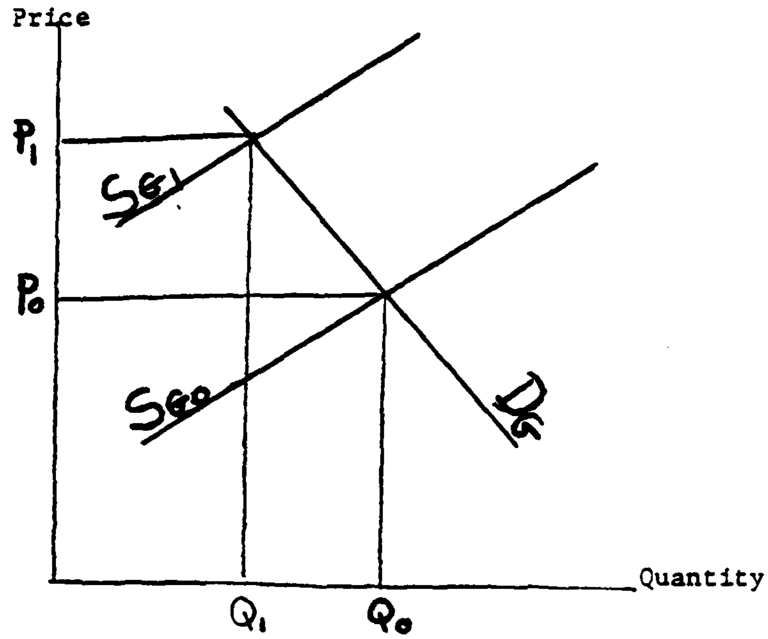
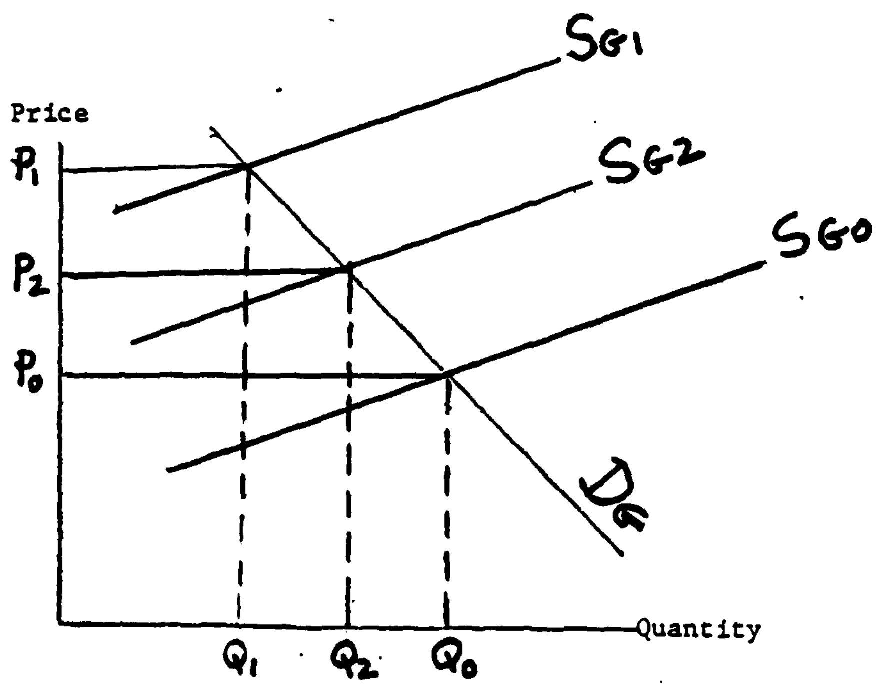


Figure 5: Secondary effect on world price and supply of drop in B's supply



$$\alpha = \frac{\Delta Q}{\Delta P} = \frac{Q_1 - Q_0}{P_1 - P_0};$$

then,

$$P_1 - P_0 = \frac{Q_1 - Q_0}{\alpha}, \text{ and}$$

$$P_1 = P_0 + \frac{Q_1 - Q_0}{\alpha} = P_0 + \frac{Q_0 - Q_1}{-\alpha} .$$

It must be emphasized that figure 4 offers only the most simplified, basic case. A key omission, for example, is the recognition that non-B's will react to this initial shift in the supply curve (in figure 4) by increasing their own production, release of inventories, etc., to try to capture additional profits. This will tend to shift the supply curve (due to the price increase) back to the right -- as shown in figure 5. Still, the supply curve is not likely to shift all the way back to its original position (S_{G_0}), since the costs of such additional production by others are likely to be higher than they were for B.

This approach -- outlined above -- is an effort to give more content to an opportunity cost version of the concept of at least one kind of dependence than we have thus far seen in the general literature on the topic. It is by no means complete. Yet it seems to us to be a step in the right direction in outlining a general schema for measuring A's dependence on particular Bs.

Within this framework it should be apparent that A might be more import dependent for commodity i on a producer of i it has no

direct dealings with than it is on its own particular supplier(s) of i. This will not necessarily be so, of course, but it could be the case. It seems intuitively quite plausible to view the matter in these terms, at least for many purposes. After all, if A is importing its i from a comparatively tiny producer (B_1) in an international market, and none from a very large producer (B_2), B_1 may have little or no capacity to influence the prevailing global market price for i while B_2 has a great deal. The measurement strategy outlined here will gauge A's import dependence on B_2 as greater than A's import dependence on B_1. One way to summarize this approach is to note that we see "indirect" import dependence as potentially at least as important as "direct" dependence. Another way to view this issue is to say that this measurement approach assumes that transaction costs are relatively small and that the markets involved are truly international institutions. We see little clear evidence to suggest otherwise. In any case, the matter is at least in principle open to empirical investigation.[12]

IV. RISK AND VULNERABILITY

That A can be harmed by B (is dependent on B) does not mean A will be harmed. Capacity does not imply intent. Moreover, signals of intent to impose harm may be a bargaining bluff. Yet calling a bargaining posture a bluff too loudly may lead to imposition of some harm.[13]

If A depends on B for X units of utility per period, there is some chance (P) that B will inflict that harm X on A within the next period. A's "expected losses" or "expected value of loss" (EVL_{t_1}) in period t_1 can be conceived most simply as

$$EVL_{t_1} = X \cdot P = \text{A's vulnerability to damage by B in period } t_1$$

Note that the <u>true</u> chance (P_A) that B will inflict the harm it can inflict on A during a particular time period (t_1) may be quite different in practice -- and certainly is in principle -- from A's subjective estimate (P_S) of that chance. Similarly, the amount of damage A expects B to be able to inflict on A (X_B) may be quite different from the amount of damage B is in fact capable of inflicting (X_A). To the extent we can gauge both the true chance and the true amount of damage B can do, we can arrive at a measure of A's true vulnerability to damage by B. The key point is that there is no necessary correspondence between A's perceived and actual vulnerability to such damage. A's subjective estimate may be higher, lower, or the same as the actual value. We need to focus closely in future work on the implications of such potential discrepancies.

A's actual vulnerability to damage by B (EVL_A) could logically increase in any of five basic ways. P_A could increase while X_A remains the same. X_A could increase while P_A

remains the same. P_A and X_A could both increase. P_A could decrease but X_A could increase more than enough to "compensate." Or X_A could decrease but P_A could increase more than enough to compensate.

Estimating P_A is obviously complex. It may seem reasonable to assume that

$P_A = f(V_B)$, where V_B equals B's expected net benefit (value) from imposing the harm on A (and where V_B itself equals the expected gross benefits to B from imposing the harm minus the expected gross costs to B from imposing the harm). But it is also quite plausible that the greater the net benefit B expects to be able to obtain from imposing the harm, the more likely A will try to either reduce the net benefit or reduce it <u>relative</u> to the benefit B receives from a negotiated solution not so damaging to A.

This in turn suggests that

$$P_A = f(V_B - VA_B)$$

may be more plausible, where VA_B is the expected net benefit from a compromise offer by A that improves for B on B's own expected utility from simply avoiding the harmful act against A.

This complexity alone, that $P_A = f(V_B - VA_B)$, makes the assess-

ment of EVL_A a highly challenging problem for further theoretical, measurement, and empirical work. But the core idea is that $EVL_A = P_A . X_A$.

P_A will generally be very low if V_B is low, and V_B may be low for a variety of reasons. A may retaliate. B may automatically lose benefits from A, e.g., revenues. Others may retaliate. B may automatically lose benefits from non-A's.

The counter-hypothesis that increased profits will necessarily accrue to B through such price increases or import-interruptions ignores at least two important points. First, it is generally reasonable to assume that producers are already trying to maximize profits at any given point in time. In general, therefore, we have little reason to assume they will benefit economically from greatly changing their level of production -- except to keep prices from falling.[14] This does not guarantee against sharp changes, but it is a strong disincentive. Secondly, producer attempts to increase short-term profits drastically will increase the chances that consumers (not just A) will strongly accelerate the pace of substitution efforts, which may well reduce the long-term profit maximization chances for the particular suppliers.

An additional factor which may reduce P_A consists in the generalized political costs to B which may result from B's efforts

to impose harm on A. These may be greater than are first apparent. After all, embargoes and price increases are very difficult to selectively impose (on a given consumer), as history has repeatedly shown. It is therefore quite plausible that B's efforts to hurt a given party (A) will have a far greater combined adverse effect upon other consumers than upon A itself. Such negative economic consequences may well redound to the net political disadvantage of party B.

Now if A depends on B, then B can if it chooses impose that hurt on A. A will be less vulnerable to damage that B can impose the less willing B is to impose that damage, at least other things equal. But the damage B can impose on A could be imposed on A even if B is unwilling to impose it. This could obviously occur if B loses control over its own activities. Internal strife (within B), accidents of weather, flooding, etc., conflict between B and third parties, or possible third party efforts to disrupt B's relations with the rest of the world are all ways in which this control might be at least partially lost.

The practical implication of this consideration is that, while A's vulnerability to the specific damage B can inflict will be smaller the less willing B is to inflict it, B's unwillingness to inflict damage is not sufficient to render A invulnerable to such damage. In short, P_A will be a function not just of V_B (and potentially of V_B-VA_B): it will also be a function of

both the likelihood that B will lose control over its own activities as well as the likelihood that, if B does lose this control, the damage will then be imposed.

V. REDUCING VULNERABILITY

Actors seeking to reduce their vulnerability to damage appear to have two broad avenues of approach. They can try to deter the damage, i.e., reduce the chances someone will try to impose it. Or they can attempt to reduce the amount by which their utility level could be damaged by other actors even if those actors should try to inflict the damage. These are not mutually exclusive. In any case, efforts to achieve either of these results have costs as well as the potential for success. There are not likely to be any guaranteed ways to achieve either result. Although some policy presciptions are tempting to view as sure moves in the right direction, we need to understand some potential pitfalls before embracing specific proposed techniques as even partial "solutions."

A general rule of thumb in dealing with vulnerability presumably should be that you want to try to reduce both the chances the damage will be imposed and the amount of damage if an actor tries to impose it, but only so long as the costs of your efforts don't outweigh the benefits you are likely to gain.[15] In applying

this rule, consider, for example, the implications vis-a-vis positive and negative dependence situations.

Assume A is, in the case of positive dependence, receiving a stream of benefits (X) from B at t_2 which he could not obtain for free elsewhere (as in figure 1). One way for A to reduce his vulnerability at t_3 is to refuse to accept any benefits from B. This will lower his dependence on B at t_3 compared to t_2: after t_3 B can impose less future harm on A than B was able to impose at t_2. But this sort of approach has the obvious disadvantage of also reducing A's utility level in the process, and represents a kind of pyrrhic victory. Despite its disadvantages, this type of strategy seems to us to bear a strong resemblance to most efforts to reduce imports (e.g., Project Independence during the Nixon-Ford Administrations) through policies such as tariffs and import quotas.

In the case of positive dependence, however, if it is possible for A to reduce its positive dependence without reducing its current (t_2) utility position, it seems entirely rational to try to do so. An obvious line of approach here is to attempt to build a network of alternative sources and substitutes able to provide some portion of the benefits A now receives from B -- in the event B should withdraw those benefits.

But note that the likely net benefits to A of efforts to build that kind of alternate benefit network will hinge on two things: 1) the actual chance B will try to withdraw the benefits it provides; 2) the additional benefit (that is, over and above the value to A of alternative sources that would be available -- should B withdraw its benefits -- even if A had not spent resources to build such a network) that this alternate network would provide to A (assuming B did withdraw) compared to A's cost of building it.

As a concrete illustration of some potential problems involved here, consider the issue of U.S. government stockpiles of crude oil -- the Strategic Petroleum Reserve (SPR). The major rationale for building up the SPR appears to be that it would provide the U.S. civilian sector with additional, badly needed oil in a severe oil crisis. Although it is sometimes assumed vital for U.S. military purposes, this has not been demonstrated. Note that SPR oil is crude oil, not militarily usable products. The military has its own, totally separate, stockpiles of usable fuel. Obviously, though, military inventories could run out. But the U.S. has (and will have for many decades) far more than adequate domestic crude oil production[16] (and refinery) capacity[17] to supply the U.S. military in wartime -- unless the U.S. is massively attacked. (If attacked, SPR (crude) oil would not be directly usable anyway.)

But how much help would extra SPR oil be to the civilian sector? On the surface, additional SPR crude oil would seem to help moderate extreme domestic prices for oil in a severe oil import disruption. Note, though, that this effect may be much smaller than often thought. The key problem is as follows.

Whatever moderating effect on prices SPR releases might temporarily have on U.S. domestic prices, they will also reduce the incentives of international oil companies to sell to U.S. consumers whatever foreign oil they might otherwise be willing to bring into the U.S.; SPR releases would thus increase their incentives to sell that foreign oil overseas (where the prevailing price was higher). To try to force the oil companies to do otherwise may be an appealing prospect. But succeeding in this effort would be a quite different proposition.

To our knowledge, no effective mechanism has yet been devised to cope with this very real problem. Thus, despite the surface appeal and emotionally attractive aspects of a large Strategic Petroleum Reserve, it is not immediately apparent that it will have anything like the advantages -- even for the U.S. civilian sector -- that are often claimed for it.

SPR releases may help moderate world oil prices in such a crisis, but since they are likely to be a relatively small proportion of the global supply available -- even in a severe oil

disruption -- the net benefit to the U.S. civilian sector may be quite small. We do not come to this conclusion happily, but the example does suggest some of the very real difficulties in devising effective ways to reduce the costs of trade disruptions -- should they occur.

In any case, it is rational for A to consider that if it can't substantially reduce its positive dependence without thereby reducing its utility, it does not gain by refusing to accept the current benefits which its dependence on B provides.

In such a case, A can still attempt to reduce the chances that those benefits which B uniquely provides will be withdrawn. Again, however, A must bear in mind that chance- reduction strategies have costs as well, and that individual strategies are not necessarily suited to the particular source of risk.

As an example of the first point, note that political concessions to suppliers so as to forestall price increases or embargoes are neither clearly necessary nor sufficient to the objective. Nor is it clear they have made or will make a difference in pricing policies for states that have offered concessions.[18] A key reason is that selective embargoes or preferential pricing schemes in global markets, while easy to try, are very difficult to enforce: the pressures to participate in "secondary markets" are usually extremely strong.

As an example of the problems in tailoring a deterrent strategy to the particular source of risk, it is well to emphasize that while credible military instruments may help deter third party efforts from harming A by severing important trade links (whether these are direct or indirect trade links), these instruments may prove powerless to deter the damage should it stem, for example, from internal strife in B.

From a policy standpoint, dependence and risk reduction strategies need to be considered from the twin perspectives of expected net benefit and suitability of the instruments. We do not mean to imply here that no such strategies can work. But it is important to attend to key limitations of specific policies so as to help decision-makers devise suitable means to achieve appropriate national objectives.

In situations of positive dependence, A's efforts to reduce the amount of damage B could impose should be devised to avoid reducing the benefits which at least B is now providing. In cases of negative dependence, A will not (normally) be obtaining any current benefits from that dependence per se (as illustrated in figure 2). Here too, though, A has rational incentives to reduce both the damage which could be done and the chances of that damage being imposed -- so long as A's costs of such efforts are less than the gains achieved thereby.

Deterrence theory and policies seem relevant here. What may not be as obvious is the pervasive formal similarity between strategic deterrence issues and strategies for reducing vulnerability to damage in the realm of economic dependence relations. This is not the place to elaborate on these similarities or on possibilities for cross-fertilization in the two subject areas. Still, in light of these issues, it is intriguing that the cornerstone of strategic deterrence theory has long been the notion of automatic, immediate and catastrophic consequences for the aggressor should it attempt to inflict harm.[19] Is it possible that a vigorous emphasis on the very likely widespread adverse effects on many nations of any efforts by B to inflict highly targeted economic harm on A could itself be a potent deterrent to B in many cases?

This sort of strategy will by no means always be sufficient. Nothing will deter an adversary whose greatest joy is inflicting harm on you and who pays no attention to likely damage to himself as a result of inflicting such harm. All one can do in such a situation is physically prevent the adversary from doing the harm he otherwise would.

Fortunately, there are few such actors in the international arena today, despite rhetoric and bargaining postures to the contrary.

VI. CONCLUSIONS

The foundation for an understanding of the extent of a given actor's dependence on another seems to reside most basically in an appreciation of the amount of harm (i.e., utility losses) the second actor can impose on the first. In this paper we have attempted to lay out what appear to be the key elements in that sort of conceptual measurement approach to the problem. The approach is by no means fully articulated here. But hopefully a useful beginning has been made.

Given this, we then set out a procedure for gauging -- at least in principle -- the extent of harm which a particular foreign producer of a good is likely to be able to inflict on a particular importer of that good: in loose terminology, our strategy can be labelled an opportunity cost framework, although we have generalized our formulation beyond the popular notion that A must be directly interacting with B to be import dependent on B.

But high dependence does not logically entail high current vulnerability to that harm. We thus set out a framework in which we conceive of vulnerability as a function of both dependence and the risk that the hurt will be imposed.

In the last section we discussed two general approaches to vulnerability reduction. In doing so we considered some potential

difficulties in using political concessions and government contingency stockpiles as instruments for vulnerability reduction. Finally, we alluded to an interesting potential parallel between the cornerstone of modern strategic deterrence theory (automaticity of adverse feedback), and the likely widespread, systematic effects of attempts by one actor (B) to impose highly focused harm on a particular, economically dependent actor (A).

NOTES

1. Assuming no simultaneous change in availability of alternative benefits.
2. An example would be an increase in B's effective control over a larger share of the supply market.
3. A's negative dependence will presumable decline here also, but this will in practice hinge on the outcome of the conflict: B might wind up even stronger relative to A (if A's defenses were damaged more).
4. See Note 1.
5. See, for example, Joseph Nye, Jr., "Independence and Interdependence," Foreign Policy, No. 22, Spring 1976, p. 133. See also Thomason, 1979.
6. This is essentially an "expected value" approach to the issue. For a general discussion see Hubert M. Blalock, Jr., Social Statistics, Revised 2nd Edition, McGraw Hill, New York, 1979, pp. 137-39.
7. See Paul Samuelson, Economics, McGraw Hill, New York, 1973, pp. 472-3.
8. For a basic discussion, see Samuelson (1973:436-8); for an excellent but highly technical treatment, see Charles River Associates A Framework for Analyzing Commodity Supply Restrictions (1976).
9. See McDougall, D. and Dernburg, T. (1963).

10. A number of these issues are also discussed in Charles River Associates (1976).

11. See Thomason (1980) for a typology of such costs.

12. One possibility is to assess links between A's politically cooperative attempts towards (1) B's it directly trades with, versus (2) B's that are major producers in the market regardless of whether A trades with them, applying suitable controls.

13. See Snyder (1972) for an excellent discussion of the dynamics of such situations.

14. "A profit-maximizer may not be an altruist; but that does not mean he is a fool." See Samuelson (1973: 490).

15. For a brilliant discussion of cost-benefit analysis, see Fischoff (1977).

16. See Ray Dafter (1979/80). For aggregate data on U.S. military fuel needs see Thomason (1981), The Defense Energy Management Plan (1980), and HASC (198).

17. See the American Petroleum Institute (1980).

18. We know of no evidence to suggest, for example, that those Western states adopting more pro-OPEC policies on Israel obtain lastingly better market prices for oil imports than those which do not.

19. See, for example, Schelling (1963).

BIBLIOGRAPHY

American Petroleum Institute, 1979-1980 Worldwide Directory, Refining, and Gas Processing, Washington, D.C., 1980.

Baldwin, D., "Interdependence and Power: A Conceptual Analysis," International Organization, 34,4, Autumn, 1980.

Blalock, H., Social Statistics, 2nd Ed. (Revised), McGraw Hill, N.Y., 1979.

Caporaso, J., "Dependence, Dependency, and Power in the Global System," International Organization, 32, 1, Winter, 1978.

Central Intelligence Agency, "The World Oil Market in the Years Ahead," ER79-10327U, August, 1979.

Congressional Budget Office, "The World Oil Market in the 1980's," Background Paper, May, 1980.

Charles River Associates, Inc., "A Framework for Analyzing Commodity Supply Restrictions," NBS-GCR-ETIP 76-24, Final Report to the Experiemental Technology Incentives Program, August, 1976.

Dafter, R., "World Oil Production," International Security, 4, 3, Winter 1979-80.

Department of Defense, Defense Energy Management Plan, 1 July 1980.

Fischoff, B., "Cost Benefit Analysis and the Art of Motorcycle Maintenance," Policy Sciences 8, 1977.

House Armed Services Committee, "Department of Defense Petroleum Requirements and Supplies," HASC No. 96-33, 1980.

Keohane, R., and Nye, J., "World Politics and the International Economic System," in C.F. Bergsten, ed., The Future of the International Economic System, Lexington Books, Lexington, Mass., 1973.

Knorr, K., ed., Historical Dimensions of National Security Problems, University of Kansas Press, 1976.

Krapels, E.N., Oil Crisis Management, Johns Hopkins Univ. Press, Baltimore, Maryland, 1980.

McDougall, D., and Dernburg, T., Macro-Economics, McGraw Hill, London, 1963.

National Security Council, Special Report: Critical Imported Minerals, Dec., 1974.

Nye, J., "Independence and Interdependence," Foreign Policy, 22, Spring, 1976.

Samuelson, P., Economics, McGraw Hill, N.Y., 1973.

Schelling, R., The Strategy of Conflict, Oxford Univ. Press, N.Y., 1963.

Snyder, G., "Crisis Bargaining," in C. Hermann, ed., International Crises, The Free Press, N.Y., 1972.

Steinbrunner, J., The Cybernetic Theory of Decision, Princeton Univ. Press, N.J., 1974.

Thomason, James, "U.S. Allies and the Carter Doctrine: Free-Riding in the Persian Gulf?" CNA Memo, April 1980.

Thomason, James, "Will the Tanks Run Dry? Fueling the Forces in Crisis and War, 1981-2000," CNA WP, April 1981.

CNA Professional Papers – 1976 to Present†

PP 141
Mizrahi, Maurice M., "Generalized Hermite Polynomials,"* 5 pp., Feb 1976 (Reprinted from the Journal of Computational and Applied Mathematics, Vol. 1, No. 4 (1975), 273-277).
*Research supported by the National Science Foundation

PP 143
Horowitz, Stanley and Sherman, Allan (LCdr., USN), "Maintenance Personnel Effectiveness in the Navy," 33 pp., Jan 1976 (Presented at the RAND Conference on Defense Manpower, Feb 1976) AD A021 581

PP 144
Durch, William J., "The Navy of the Republic of China – History, Problems, and Prospects," 66 pp., Aug 1976 (Published in "A Guide to Asiatic Fleets," ed. by Barry M. Blechman and Robert Berman, Naval Institute Press) AD A030 460

PP 145
Kelly, Anne M., "Port Visits and the "Internationalist Mission" of the Soviet Navy," 36 pp., Apr 1976, AD A023 436

PP 147
Kessler, J. Christian, "Legal Issues in Protecting Offshore Structures," 33 pp., Jun 1976 (Prepared under task order N00014-68-A-0091-0023 for ONR) AD A028 389

PP 149
Squires, Michael L., "Counterforce Effectiveness: A Comparison of the Tsipis "K" Measure and a Computer Simulation," 24 pp., Mar 1976 (Presented at the International Study Association Meetings, 27 Feb 1976) AD A022 591

PP 150
Kelly, Anne M. and Petersen, Charles, "Recent Changes in Soviet Naval Policy: Prospects for Arms Limitations in the Mediterranean and Indian Ocean," 28 pp., Apr 1976, AD A 023 723

PP 151
Horowitz, Stanley A., "The Economic Consequences of Political Philosophy," 8 pp., Apr 1976 (Reprinted from Economic Inquiry, Vol. XIV, No 1, Mar 1976)

PP 152
Mizrahi, Maurice M., "On Path Integral Solutions of the Schrodinger Equation, Without Limiting Procedure,"* 10 pp., Apr 1976 (Reprinted from Journal of Mathematical Physics, Vol. 17, No. 4 (Apr 1976), 566-575)
*Research supported by the National Science Foundation

PP 153
Mizrahi, Maurice M., "WKB Expansions by Path Integrals, With Applications to the Anharmonic Oscillator,"* 137 pp., May 1976, AD A025 440
*Research supported by the National Science Foundation

PP 154
Mizrahi, Maurice M., "On the Semi-Classical Expansion in Quantum Mechanics for Arbitrary Hamiltonians," 19 pp., May 1976 (Published in Journal of Mathematical Physics, Vol 18, No 4, pp. 789-790, Apr 1977), AD A025 441

PP 155
Squires, Michael L., "Soviet Foreign Policy and Third World Nations," 26 pp., Jun 1976 (Prepared for presentation at the Midwest Political Science Association meetings, Apr 30, 1976) AD A028 388

PP 156
Stallings, William, "Approaches to Chinese Character Recognition," 12 pp., Jun 1976 (Reprinted from Pattern Recognition (Pergamon Press), Vol 8, pp. 87-98, 1976) AD A028 692

PP 157
Morgan, William F., "Unemployment and the Pentagon Budget: Is There Anything in the Empty Pork Barrel?" 20 pp., Aug 1976 AD A030 455

PP 158
Haskell, LCdr. Richard D. (USN), "Experimental Validation of Probability Predictions," 25 pp., Aug 1976 (Presented at the Military Operations Research Society Meeting, Fall 1976) AD A030 458

PP 159
McConnell, James M., "The Gorshkov Articles, The New Gorshkov Book and Their Relation to Policy," 93 pp., Jul 1976 (Published in Soviet Naval Influence: Domestic and Foreign Dimensions, ed. by M. McCGwire and J. McDonnell; New York; Praeger, 1977) AD A029 227

PP 160
Wilson, Desmond P., Jr., "The U.S. Sixth Fleet and the Conventional Defense of Europe," 50 pp., Sep 1976, AD A030 457

PP 161
Melich, Michael E. and Peet, Vice Adm. Ray (USN, Retired), "Fleet Commanders: Afloat or Ashore?" 9 pp., Aug 1976 (Reprinted from U.S. Naval Institute Proceedings, Jun 1976) AD A030 456

PP 162
Friedheim, Robert L., "Parliamentary Diplomacy," 106 pp. Sep 1976 AD A033 306

PP 163
Lockman, Robert F., "A Model for Predicting Recruit Losses," 9 pp., Sep 1976 (Presented at the 84th annual convention of the American Psychological Association, Washington, D.C., 4 Sep 1976) (Published in Defense Manpower Policy (Richard V. L. Cooper, ed.), The Rand Corporation, 1979), AD A030 459

PP 164
Mahoney, Robert B., Jr., "An Assessment of Public and Elite Perceptions in France, The United Kingdom, and the Federal Republic of Germany," 31 pp., Feb 1977 (Presented at Conference "Perception of the U.S. – Soviet Balance and the Political Uses of Military Power" sponsored by Director, Advanced Research Projects Agency, April 1976) AD A036 599

PP 165
Jondrow, James M. "Effects of Trade Restrictions on Imports of Steel," 67 pp., November 1976, (Delivered at ILAB Conference in Dec 1976) AD A094 798

PP 166 – Revised
Feldman, Paul, "Why It's Difficult to Change Regulation," Oct 1976, AD A037 682

PP 167
Kleinman, Samuel, "ROTC Service Commitments: a Comment," 4 pp., Nov 1976, (Published in Public Choice, Vol. XXIV, Fall 1976) AD A033 305

PP 168
Lockman, Robert F., "Revalidation of CNA Support Personnel Selection Measures," 36 pp., Nov 1976

PP 169
Jacobson, Louis S., "Earnings Losses of Workers Displaced from Manufacturing Industries," 38 pp., Nov 1976, (Delivered at ILAB Conference in Dec 1976), AD A039 809

PP 170
Brechling, Frank P., "A Time Series Analysis of Labor Turnover," Nov 1976. (Delivered at ILAB Conference in Dec 1976), AD A096 630

PP 171
Jordan, A. S.* and Ralston, J. M., "A Diffusion Model for GaP Red LED Degradation," 10 pp., Nov 1976, (Published in Journal of Applied Physics, Vol. 47, pp. 4518-4527, Oct 1976)
*Bell Laboratories

PP 172
Classen, Kathleen P., "Unemployment Insurance and the Length of Unemployment," Dec 1976, (Presented at the University of Rochester Labor Workshop on 16 Nov 1976)

PP 173
Kleinman, Samuel D., "A Note on Racial Differences in the Added-Worker/Discouraged-Worker Controversy," 2 pp., Dec 1976, (Published in the American Economist, Vol. XX, No. 1, Spring 1976)

PP 174
Mahoney, Robert B., Jr., "A Comparison of the Brookings and International Incidents Projects," 12 pp. Feb 1977 AD A037 206

PP 175
Levine, Daniel; Stoloff, Peter and Spruill, Nancy, "Public Drug Treatment and Addict Crime," June 1976, (Published in Journal of Legal Studies, Vol. 5, No. 2)

PP 176
Felix, Wendi, "Correlates of Retention and Promotion for USNA Graduates," 38 pp., Mar 1977, AD A039 040

PP 177
Lockman, Robert F. and Warner, John T., "Predicting Attrition: A Test of Alternative Approaches," 33 pp. Mar 1977. (Presented at the OSD/ONR Conference on Enlisted Attrition, Xerox International Training Center, Leesburg, Virginia, 4-7 April 1977), AD A039 047

PP 178
Kleinman, Samuel D., "An Evaluation of Navy Unrestricted Line Officer Accession Programs," 23 pp April 1977, (Presented at the NATO Conference on Manpower Planning and Organization Design, Stresa, Italy, 20 June 1977), AD A039 048

†CNA Professional Papers with an AD number may be obtained from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22151. Other papers are available from the Management Information Office, Center for Naval Analyses, 2000 North Beauregard Street, Alexandria, Virginia 22311. An Index of Selected Publications is also available on request. The index includes a Listing of Professional Papers; with abstracts; issued from 1969 to June 1980.

PP 179
Stoloff, Peter H. and Balut, Stephen J., "Vacate: A Model for Personnel Inventory Planning Under Changing Management Policy," 14 pp. April 1977, (Presented at the NATO Conference on Manpower Planning and Organization Design, Stresa, Italy, 20 June 1977), AD A039 049

PP 180
Horowitz, Stanley A. and Sherman, Allan, "The Characteristics of Naval Personnel and Personnel *Performance*," 16 pp. April 1977, (Presented at the NATO Conference on Manpower Planning and Organization Design, Stresa, Italy, 20 June 1977), AD A039 050

PP 181
Balut, Stephen J. and Stoloff, Peter, "An Inventory Planning Model for Navy Enlisted Personnel," 35 pp., May 1977 (*Prepared for presentation at the* Joint National Meeting of the Operations Research Society of America and The Institute for Management Science. 9 May 1977, San Francisco, California), AD A042 221

PP 182
Murray, Russell, 2nd, "The Quest for the Perfect Study or My First 1138 Days at CNA," 57 pp., April 1977

PP 183
Kassing, David, "Changes in Soviet Naval Forces," 33 pp., November, 1976, (*Published as part of* Chapter 3, "General Purpose Forces: Navy and Marine Corps," in Arms, Men, and Military Budgets, Francis P. Hoeber and William Schneider, Jr. (eds.), (Crane, Russak & Company, Inc.: New York), 1977), AD A040 106

PP 184
Lockman, Robert F., "An Overview of the OSD/ONR Conference on First Term Enlisted Attrition," 22 pp. June 1977, (Presented to the 39th MORS Working Group on Manpower and Personnel Planning, Annapolis, Md., 28-30 Jun 1977), AD A043 618

PP 185
Kassing, David, "New Technology and Naval Forces in the South Atlantic," 22 pp. (This paper was the basis for a presentation made at the *Institute for* Foreign Policy Analyses, Cambridge, Mass., 28 April 1977), AD A043 619

PP 186
Mizrahi, Maurice M., "Phase Space Integrals, Without Limiting Procedure," 31 pp., May 1977, (Invited paper presented at the 1977 NATO Institute on Path Integrals and Their Application in Quantum Statistical, and Solid State Physics, Antwerp, Belgium, July 17-30, 1977) (Published in *Journal of Mathematical Physics* 19(1), pp. 298-307, Jan 1978, with Erratum in same journal 21 (1980), p. 1965) AD A040 107

PP 187
Coile, Russell C., "Nomography for Operations Research," 35 pp., April 1977 (Presented at the Joint National Meeting of the Operations Research *Society of America and The Institute for* Management Services, San Francisco, California, 9 May 1977), AD A043 620

PP 188
Durch, William J., "Information Processing and Outcome Forecasting for Multilateral Negotiations: Testing One Approach," 53 pp., May 1977 (Prepared for presentation to the 18th *Annual Convention of the International Studies Association*, Chase-Park Plaza Hotel, St. Louis, Missouri, March 16-20, 1977), AD A042 222

PP 189
Coile, Russell C., "*Error Detection in Computerized* Information Retrieval Data Bases," July, 1977, 13 pp. (Presented at the Sixth Cranfield International Conference on Mechanized Information Storage and Retrieval Systems, Cranfield Institute of Technology, *Cranfield*, Bedford, England, 26-29 July 1977), AD A043 580

PP 190
Mahoney, Robert B., Jr., "European Perceptions and East-West Competition," 96 pp., July 1977 (Prepared for presentation at the annual meeting of *the International* Studies Association, St. Louis, Mo., March, 1977), AD A043 661

PP 191
Sawyer, Ronald, "The Independent Field Assignment: One Man's View," August 1977, 25 pp.

PP 192
Holen, Arlene, "Effects of Unemployment Insurance Entitlement on Duration and Job Search Outcome," August 1977, 6 pp., (Reprinted from Industrial and Labor Relations Review, Vol., 30, No. 4, Jul 1977)

PP 193
Horowitz, Stanley A., "A Model of Unemployment *Insurance and the Work Test*," August 1977, 7 pp. (Reprinted from Industrial and Labor Relations Review, Vol. 30, No. 40, Jul 1977)

PP 194
Classen, Kathleen P., "The Effects of Unemployment Insurance on the Duration of Unemployment and Subsequent Earnings," August 1977, 7 pp. (*Reprinted* from Industrial and Labor Relations Review, Vol. 30, No. 40, Jul 1977)

PP 195
Brechling, Frank, "Unemployment Insurance Taxes and Labor Turnover: Summary of Theoretical Findings," 12 pp. (Reprinted from Industrial and Labor Relations Review, Vol. 30, No. 40, Jul 1977)

PP 196
Ralston, J. M. and Lorimor, O. G., "Degradation of Bulk Electroluminescent Efficiency in Zn, O-Doped GaP LED's," July 1977, 3 pp. (Reprinted from IEEE *Transactions* on Electron Devices, Vol. ED-24, No. 7, July 1977)

PP 197
Wells, Anthony R., "The Centre for Naval Analyses," 14 pp., Dec 1977, AD A049 107

PP 198
Classen, Kathleen P., "The Distributional Effects of Unemployment Insurance," 25 pp., Sept. 1977 (Presented at a Hoover Institution Conference on *Income Distribution*, Oct 7-8, 1977), AD A054 423

PP 199
Durch, William J., "Revolution From A F.A.R. – The Cuban Armed Forces in Africa and the Middle East," Sep 1977, 16 pp., AD A046 268

PP 200
Powers, Bruce F., "The United States Navy," 40 pp. Dec 1977 (Published as a chapter in The U.S. War Machine by Salamander Books, England, 1978), AD A049 108

PP 201
Durch, William J., "The Cuban Military in Africa *and The Middle East: From Algeria to Angola*," Sep 1977, 67 pp., AD A045 675

PP 202
Feldman, Paul, "Why Regulation Doesn't Work," (Reprinted from Technological Change and Welfare in the Regulated Industries, Brookings Reprint 219, 1971, and Review of Social Economy, Vol. XXIX, March, 1971, No. 1.) Sep 1977, 8 pp.

PP 203
Feldman, Paul, "*Efficiency, Distribution, and the* Role of Government in a Market Economy," (Reprinted from The Journal of Political Economy, Vol. 79, No. 3, May/June 1971.) Sep 1977, 19 pp., AD A045 675

PP 204
Wells, Anthony R., "The 1967 June War: Soviet Naval Diplomacy and The Sixth Fleet – A Reappraisal," Oct 1977, 36 pp., AD A047 236

PP 205
Coile, Russell C., "A Bibliometric Examination of the Square Root Theory of Scientific Publication Productivity," (*Presented at the annual meeting of* the American Society for Information Science, Chicago, Illinios, 29 *September* 1977.) Oct 1977, 6 pp., AD A047 237

PP 206
McConnell, James M., "Strategy and Missions of the Soviet Navy in the Year 2000," 48 pp., Nov 1977 (Presented at a Conference on Problems of Sea Power as we Approach the 21st Century, sponsored by the American Enterprise Institute for Public Policy Research, 6 October 1977, and subsequently published in a collection of papers by the Institute), AD A047 244

PP 207
Goldberg, Lawrence, "Cost-Effectiveness of Potential Federal Policies Affecting Research & Development *Expenditures in the Auto, Steel and* Food Industries," 36 pp., Oct 1977, (Presented at Southern Economic Association Meetings beginning 2 November 1977), AD A046 269

PP 208
Roberts, Stephen S., "The Decline of the Overseas Station Fleets: The United States Asiatic Fleet and the Shanghai Crisis, 1932," 18 pp., Nov 1977 (Reprinted from The American Neptune, Vol. XXXVII, No. 3, July 1977), AD A047 245

PP 209 – Classified.

PP 210
Kassing, David, "Protecting The Fleet," 40 pp., Dec 1977 (Prepared for the American Enterprise Institute Conference on Problems of Sea Power as We Approach *the 21st Century*, October 6-7, 1977), AD A049 109

PP 211
Mizrahi, Maurice M., "On Approximating the Circular Coverage Function," 14 pp., Feb 1978, AD A054 429

PP 212
Mangel, Marc, "On Singular Characteristic Initial Value Problems with Unique Solutions," 20 pp., Jun 1978, AD A058 535

PP 213
Mangel, Marc, "Fluctuations in Systems with Multiple Steady States. Application to Lanchester Equations," 12 pp., Feb 78, (Presented at the First Annual Workshop on the Information Linkage Between Applied Mathematics and Industry, Naval PG School, Feb 23-25, 1978), AD A071 472

PP 214
Weinland, Robert G., "A Somewhat Different View of The Optimal Naval Posture," 37 pp., Jun 1978 (Presented at the 1976 Convention of the American Political Science Association (APSA/IUS Panel on "Changing Strategic Requirements and Military Posture"), Chicago, Ill., September 2, 1976), AD A056 228

PP 215
Coile, Russell C., "Comments on: Principles of Information Retrieval by Manfred Kochen," 10 pp., Mar 78, (Published as a Letter to the Editor, Journal of Documentation, Vol. 31, No. 4, pages 298-301, December 1975), AD A054 426

PP 216
Coile, Russell C., "Lotka's Frequency Distribution of Scientific Productivity," 18 pp., Feb 1978, (Published in the Journal of the American Society for Information Science, Vol. 28, No. 6, pp. 366-370, November 1977), AD A054 425

PP 217
Coile, Russell C., "Bibliometric Studies of Scientific Productivity," 17 pp., Mar 78, (Presented at the Annual meeting of the American Society for Information Science held in San Francisco, California, October 1976), AD A054 442

PP 218 – Classified.

PP 219
Huntzinger, R. LaVar, "Market Analysis with *Rational Expectations: Theory and Estimation*," 60 pp., Apr 78, AD A054 422

PP 220
Maurer, Donald E., "*Diagonalization* by Group Matrices," 26 pp., Apr 78, AD A054 443

PP 221
Weinland, Robert G., "Superpower Naval Diplomacy in the October 1973 Arab-Israeli War," 76 pp., Jun 1978 (Published in Seapower in the Mediterranean: Political Utility and Military Constraints, The Washington Papers No. 61, Beverly Hills and London: Sage Publications, 1979) AD A055 564

PP 222
Mizrahi, Maurice M., "Correspondence Rules and Path Integrals," 30 pp., Jun 1978 (Invited paper presented at the CNRS meeting on "Mathematical Problems in Feynman's Path Integrals," Marseille, France, May 22-26, 1978) (Published in Springer Verlag Lecture Notes in Physics, 106, (1979), 234-253) AD A055 536

PP 223
Mangel, Marc, "Stochastic Mechanics of Molecule-Ion Molecule Reactions," 21 pp., Jun 1978, AD A056 227

PP 224
Mangel, Marc, "Aggregation, Bifurcation, and Extinction In Exploited Animal Populations*," 48 pp., Mar 1978, AD A058 536
*Portions of this work were started at the Institute of Applied Mathematics and Statistics, University of British Columbia, Vancouver, B.C., Canada

PP 225
Mangel, Marc, "Oscillations, Fluctuations, and the Hopf Bifurcation*," 43 pp., Jun 1978, AD A058 537
*Portions of this work were completed at the Institute of Applied Mathematics and Statistics, University of British Columbia, Vancouver, Canada.

PP 226
Ralston, J. M. and J. W. Mann*, "Temperature and Current Dependence of Degradation in Red-Emitting GaP LEDs," 34 pp., Jun 1978 (Published in Journal of Applied Physics, 50, 3630, May 1979) AD A058 538
*Bell Telephone Laboratories, Inc.

PP 227
Mangel, Marc, "Uniform Treatment of Fluctuations at Critical Points," 50 pp., May 1978, AD A058 539

PP 228
Mangel, Marc, "Relaxation at *Critical Points*: Deterministic and Stochastic Theory," 54 pp., Jun 1978, AD A058 540

PP 229
Mangel, Marc, "Diffusion Theory of Reaction Rates, *I: Formulation and Einstein-Smoluchowski* Approximation," 50 pp., Jan 1978, AD A058 541

PP 230
Mangel, Marc, "*Diffusion* Theory of Reaction Rates, II Ornstein-Uhlenbeck Approximation," 34 pp., Feb 1978, AD A058 542

PP 231
Wilson, Desmond P., Jr., "Naval Projection Forces: *The Case for a Responsive MAF*," Aug 1978, AD A058 543

PP 232
Jacobson, Louis, "Can Policy Changes Be Made Acceptable to Labor?" Aug 1978 (Submitted for publication in Industrial and Labor Rel[illegible] Review), AD A061 528

PP 233
Jacobson, Louis, "An Alternative Explanation of the Cyclical Pattern of Quits," 23 pp., Sep 1978

PP 234 – Revised
Jondrow, James and Levy, Robert A., "Does Federal Expenditure Displace State and Local Expenditure: The Case of Construction Grants," 25 pp., Oct 1979, AD A061 529

PP 235
Mizrahi, Maurice M., "The Semiclassical Expansion of the Anharmonic-Oscillator Propagator," 41 pp., Oct 1978 (Published in Journal of Mathematical Physics 20 (1979), pp. 844-855), AD A061 538

PP 237
Maurer, Donald, "A Matrix Criterion for Normal Integral Bases," 10 pp., Jan 1979 (Published in the Illinois Journal of Mathematics, Vol. 22 (1978), pp. 672-681

PP 238
Utgoff, Kathleen Classen, "Unemployment Insurance and The Employment Rate," 20 pp., Oct 1978 (Presented at the Conference on Economic Indicators and Performance: The Current Dilemma Facing Government and Business Leaders, presented by Indiana University Graduate School of Business), AD A061 527

PP 239
Trost, R. P. and Warner, J. T., "The Effects of Military Occupational Training on Civilian Earnings: An Income Selectivity Approach," 38 pp., Nov 1979, AD A077 831

PP 240
Powers, Bruce, "Goals of the Center for Naval Analyses," 13 pp., Dec 1978, AD A063 759

PP 241
Mangel, Marc, "Fluctuations at Chemical Instabilities," 24 pp., Dec 1978 (Published in Journal of Chemical Physics, Vol. 69, No. 8, Oct 15, 1978), AD A063 787

PP 242
Simpson, William R., "The Analysis of Dynamically Interactive Systems (Air Combat by the Numbers)," 160 pp., Dec 1978, AD A063 760

PP 243
Simpson, William R., "A Probabilistic Formulation of Murphy Dynamics as Applied to the Analysis of Operational Research Problems," 18 pp., Dec 1978, AD A063 761

PP 244
Sherman, Allan and Horowitz, Stanley A., "Maintenance Costs of Complex Equipment," 20 pp., Dec 1978 (Published By The American Society of Naval Engineers, Naval Engineers Journal, Vol. 91, No. 6, Dec 1979) AD A071 473

PP 245
Simpson, William R., "The Accelerometer Methods of Obtaining Aircraft Performance from Flight Test Data (Dynamic Performance Testing)," 403 pp., Jun 1979, AD A075 226

PP 246
Brechling, Frank, "Layoffs and Unemployment *Insurance*," 35 pp., Feb 1979 (Presented at the NBER Conference on "Low Income Labor Markets," Chicago, Jun 1978), AD A096 629

P 248
Thomas, James A., Jr., "The Transport Properties of Dilute Gases in Applied Fields," 183 pp., Mar 1979, AD A096 464

PP 249
Glasser, Kenneth S., "A Secretary Problem with a Random Number of Choices," 23 pp., Mar 1979

PP 250
Mangel, Marc, "Modeling Fluctuations in Macroscopic Systems," 26 pp., Jun 1979

PP 251
Trost, Robert P., "The Estimation and Interpretation of Several Selectivity Models," 37 pp., Jun 1979, AD A075 941

PP 252
Nunn, Walter R., "Position Finding with Prior Knowledge of Covariance Parameters," 5 pp., Jun 1979 (Published in IEEE Transactions on Aerospace & Electronic Systems, Vol. AES-15, No. 3, March 1979

PP 253
Glasser, Kenneth S., "The d-Choice Secretary Problem," 32 pp., Jun 1979, AD A075 225

PP 254
Mangel, Marc and Quanbeck, David B., "Integration of a Bivariate Normal Over an Offset Circle," 14 pp., Jun 1979, AD A096 471

PP 255 – Classified, AD B051 441L

PP 256
Maurer, Donald E., "Using Personnel Distribution Models," 27 pp., Feb 1980, AD A082 218

PP 257
Thaler, R., "Discounting and Fiscal Constraints: Why Discounting is Always Right," 10 pp., Aug 1979, AD A075 224

PP 258
Mangel, Marc S. and Thomas, James A., Jr. "Analytical Methods in Search Theory," 86 pp., Nov 1979, AD A077 832

PP 259
Glass, David V.; Hsu, Ih-Ching; Nunn, Walter R. and Perin, David A., "A Class of Commutative Markov Matrices," 17 pp., Nov 1979, AD A077 833

PP 260
Mangel, Marc S. and Cope, Davis K., "Detection Rate and Sweep Width in Visual Search," 14 pp., Nov 1979, AD A077 834

PP 261
Vila, Carlos L.; Zvijac, David J. and Ross, John, "Franck-Condon Theory of Chemical Dynamics. VI. Angular Distributions of Reaction Products," 14 pp., Nov 1979 (Reprinted from Journal Chem. Phys. 70(12), 15 Jun 1979), AD A076 287

PP 262
Petersen, Charles C., "Third World Military Elites in Soviet Perspective," 50 pp., Nov 1979, AD A077 835

PP 263
Robinson, Kathy I., "Using Commercial Tankers and Containerships for Navy Underway Replenishment," 25 pp., Nov 1979, AD A077 836

PP 264
Weinland, Robert G., "The U.S. Navy in the Pacific: Past, Present, and Glimpses of the Future," 31 pp., Nov 1979 (Delivered at the International Symposium on the Sea, sponsored by the International Institute for Strategic Studies, The Brookings Institution and the Yomiuri Shimbun, Tokyo, 16-20 Oct 1978) AD A066 837

PP 265
Weinland, Robert G., "War and Peace in the North: Some Political Implications of the Changing Military Situation in Northern Europe," 18 pp., Nov 1979 (Prepared for presentation to the "Conference of the Nordic Balance in Perspective: The Changing Military and Political Situation," Center for Strategic and International Studies, Georgetown University, Jun 15-16, 1978) AD A077 838

PP 266
Utgoff, Kathy Classen, and Brechling, Frank, "Taxes and Inflation," 25 pp., Nov 1979, AD A081 194

PP 267
Trost, Robert P., and Vogel, Robert C., "The Response of State Government Receipts to Economic Fluctuations and the Allocation of Counter-Cyclical Revenue Sharing Grants," 12 pp., Dec 1979 (Reprinted from the Review of Economics and Statistics, Vol. LXI, No. 3, August 1979)

PP 268
Thomason, James S., "Seaport Dependence and Inter-State Cooperation: The Case of Sub-Saharan Africa," 141 pp., Jan 1980, AD A081 193

PP 269
Weiss, Kenneth G., "The Soviet Involvement in the Ogaden War," 42 pp., Jan 1980 (Presented at the Southern Conference on Slavic Studies in October, 1979), AD A082 219

PP 270
Remnek, Richard, "Soviet Policy in the Horn of Africa: The Decision to Intervene," 52 pp., Jan 1980 (To be published in "The Soviet Union in the Third World: Success or Failure," ed. by Robert H. Donaldson, Westview Press, Boulder, Co., Summer 1980), AD A081 195

PP 271
McConnell, James, "Soviet and American Strategic Doctrines: One More Time," 43 pp., Jan 1980, AD A081 192

PP 272
Weiss, Kenneth G., "The Azores in Diplomacy and Strategy, 1940-1945, 46 pp., Mar 1980, AD A085 094

PP 273
Nakada, Michael K., "Labor Supply of Wives with Husbands Employed Either Full Time or Part Time," 39 pp., Mar 1980, AD A082 220

PP 275
Goldberg, Lawrence, "Recruiters Advertising and Navy Enlistments," 34 pp., Mar 1980, AD A082 221

PP 276
Goldberg, Lawrence, "Delaying an Overhaul and Ship's Equipment," 40 pp., May 1980, AD A085 095

PP 277
Mangel, Marc, "Small Fluctuations in Systems with Multiple Limit Cycles," 19 pp., Mar 1980 (Published in SIAM J. Appl. Math., Vol. 38, No. 1, Feb 1980) AD A086 229

PP 278
Mizrahi, Maurice, "A Targeting Problem: Exact vs. Expected-Value Approaches," 23 pp., Apr 1980, AD A085 096

PP 279
Walt, Stephen M., "Causal Inferences and the Use of Force: A Critique of Force Without War," 50 pp., May 1980, AD A085 097

PP 280
Goldberg, Lawrence, "Estimation of the Effects of A Ship's Steaming on the Failure Rate of its Equipment: An Application of Econometric Analysis," 25 pp., April 1980, AD A085 098

PP 281
Mizrahi, Maurice M., "Comment on 'Discretization Problems of Functional Integrals In Phase Space'," 2 pp., May 1980, AD A094 994

PP 283
Dismukes, Bradford, "Expected Demand for the U.S. Navy to Serve as An Instrument of U.S. Foreign Policy: Thinking About Political and Military Environmental Factors," 30 pp., April 1980, AD A085 099

PP 284
J. Keilson,* W. Nunn, and U. Sumita,** "The Laguerre Transform," 119 pp., May 1980
*The Graduate School of Management, University of Rochester and the Center for Naval Analyses
**The Graduate School of Management, University of Rochester, AD A085 100

PP 285
Remnek, Richard B., "Superpower Security Interests in the Indian Ocean Area," 26 pp., Jun 1980 AD A087 113

PP 286
Mizrahi, Maurice M., "On the WKB Approximation to the Propagator for Arbitrary Hamiltonians," 25 pp., Aug 1980 (Published in Journal of Math. Phys., 22 (1) Jan 1981), AD A091 307

PP 287
Cope, Davis, "Limit Cycle Solutions of Reaction-Diffusion Equations," 325 pp., Jun 1980 AD A087 114

PP 288
Golman, Walter, "Don't Let Your Slides Flip You: A Painless Guide to Visuals That Really Aid," 28 pp., Oct 1980

PP 289
Robinson, Jack, "Adequate Classification Guidance – A Solution and a Problem," 7 pp., Aug 1980, AD A091 212

PP 290
Watson, Gregory H., "Evaluation of Computer Software in an Operational Environment," 17 pp., Aug 1980, AD A091 213

PP 291
Maddala, G. S.* and Trost, R. P., "Some Extensions of the Nerlove Press Model," 17 pp., Oct 1980, AD A091 946
*University of Florida

PP 292
Thomas, Jr., James A., "The Transport Properties of Binary Gas Mixtures in Applied Magnetic Fields," 10 pp., Sept 1980 (Published in Journal of Chemical Physics 72 (10), 15 May 1980

PP 293
Thomas, Jr., James A., "Evaluation of Kinetic Theory Collision Integrals Using the Generalized Phase Shift Approach," 12 pp., Sept 1980 (Printed in Journal of Chemical Physics 72 (10), 15 May 1980

PP 294
Roberts, Stephen S., "French Naval Policy Outside of Europe," 30 pp., Sept 1980 (Presented at the Conference of the Section on Military Studies, International Studies Association Kiawah Island, S.C.), AD A091 306

PP 295
Roberts, Stephen S., "An Indicator of Informal Empire: Patterns of U.S. Navy Cruising on Overseas Stations, 1869-1897," 40 pp., Sept 1980 (Presented at Fourth Naval History Symposium, US Naval Academy, 26 October 1979, AD A091 316

PP 296
Dismukes, Bradford and Petersen, Charles C., "Maritime Factors Affecting Iberian Security," (Factores Maritimos Que Afectan La Securidad Iberica) 14 pp., Oct 1980, AD A092 733

PP 297 – Classified

PP 298
Mizrahi, Maurice M., "A Markov Approach to Large Missile Attacks," 31 pp., Jan 1981, AD A096 159

PP 299
Jondrow, James M. and Robert A. Levy, "Wage Leadership in Construction, 19 pp., Jan 1981, AD A094 797

PP 300
Jondrow, James and Peter Schmidt*, "On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model," 11 pp., Jan 1981, AD A096 159
*Michigan State University

PP 301
Jondrow, James M.; Levy, Robert A. and Hughes, Claire, "Technical Change and Employment in Steel, Autos, Aluminum, and Iron Ore, 17 pp., Mar 1981

PP 302
Jondrow, James M. and Levy, Robert A., "The Effect of Imports on Employment Under Rational Expectations," 19 pp., Apr 1981

PP 304
Duffy, Michael K.; Greenwood, Michael J.* and McDowell, John M.**, "A Cross-Sectional Model of Annual Interregional Migration and Employment Growth: Intertemporal Evidence of Structural Change, 1958-1975," 31 pp., Apr 1981
*University of Colorado
**Arizona State University

PP 305
Nunn, Laura H., "An Introduction to the Literature of Search Theory," 32 pp., Jun 1981

PP 306
Anger, Thomas E., "What Good Are Warfare Models?" 7 pp., May 1981

PP 307
Thomason, James, "Dependence, Risk, and Vulnerability," 43 pp., Jun 1981

PP 309
Weinland, Robert G., "An (The?) Explanation of the Soviet Invasion of Afghanistan," 44 pp., May 1981

PP 310
Stanford, Janette M. and Tai Te Wu*, "A Predictive Method for Determining Possible Three-dimensional Foldings of Immunoglobulin Backbones Around Antibody Combining Sites," 19 pp., Jun 1981 (Published in J. theor. Biol. (1981) 88, 421-439
*Northwestern University, Evanston, IL

PP 311
Marianne Bowes, Frank P. R. Brechling and Kathleen P. Classen Utgoff, "An Evaluation of UI Funds," 13 pp., May 1981 (Published in National Commission on Unemployment Compensation's Unemployment Compensation: Studies and Research, Volume 2, July 1980)

PP 312
Jondrow, James; Bowes, Marianne and Levy, Robert, "The Optimum Speed Limin," 23 pp., Jun 1981